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ABSTRACT

Teachers and researchers alike have advocated over the last decade writing across the curriculum, which has tremendous potential both for improving the writing process and as a tool for helping students develop subject matter understandings. In particular, evidence shows that writing-to-learn has promise as a powerful tool for supporting students through a process of conceptual change in elementary school science; however, little research has been done in this area. Many researchers believe that social and instruction norms for school science and writing form early and are strongly held. Therefore, the teachers using writing-to-learn in science has a dual challenge: to change the existing norms of science learning from focusing on memorizing facts or doing "neat activities" to developing connections and understanding relationships among ideas and to change the norms for writing from knowledge telling, with the teacher taking on the role of evaluator, to using writing as a tool for puzzling over ideas and making connections. This paper shows how much change is possible in the course of one science unit, given the existing social and instruction norms of both teacher and students in a third-grade science class. It tells of the struggle the teacher went through in trying to use both oral and written discourse in new ways in order to promote student knowledge growth in science and the struggle that students went through as they were presented with the new way of thinking about science and writing. Included is a description of the teacher's gradual shift back to a more traditional way of teaching as she began to "fit" the ideas of conceptual change science teaching and writing-to-learn within her more familiar framework of exposing the students to ideas, finding out what they think, and telling them the scientific concept. Also included is an analysis of two students' writing in science and their perceptions of the ways in which this writing resembles or differs from other writing done in science across the year. (Author)

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Series No. 54

WRITING-TO-LEARN IN A CONCEPTUAL CHANGE SCIENCE UNIT

Kathleen L. Peasley, Cheryl L. Rosaen,
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The **Center for the Learning and Teaching of Elementary Subjects** was awarded to Michigan State University in 1987 after a nationwide competition. Funded by the Office of Educational Research and Improvement, U.S. Department of Education, the Elementary Subjects Center is a major project housed in the Institute for Research on Teaching (IRT). The program focuses on conceptual understanding, higher order thinking, and problem solving in elementary school teaching of mathematics, science, social studies, literature, and the arts. Center researchers are identifying exemplary curriculum, instruction, and evaluation practices in the teaching of these school subjects; studying these practices to build new hypotheses about how the effectiveness of elementary schools can be improved; testing these hypotheses through school-based research; and making specific recommendations for the improvement of school policies, instructional materials, assessment procedures, and teaching practices. Research questions include, What content should be taught when teaching these subjects for understanding and use of knowledge? How do teachers concentrate their teaching to use their limited resources best? and In what ways is good teaching subject matter-specific?

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Abstract

Teachers and researchers alike have advocated over the last decade writing across the curriculum, which has tremendous potential both for improving the writing process and as a tool for helping students develop subject matter understandings. In particular, evidence shows that writing-to-learn has promise as a powerful tool for supporting students through a process of conceptual change in elementary school science; however, little research has been done in this area. Many researchers believe that social and instructional norms for school science and writing form early and are strongly held. Therefore, the teacher using writing-to-learn in science has a dual challenge: to change the existing norms of science learning from focusing on memorizing facts or doing "neat activities" to developing connections and understanding relationships among ideas and to change the norms for writing from knowledge telling, with the teacher taking on the role of evaluator, to using writing as a tool for puzzling over ideas and making connections. This paper shows how much change is possible in the course of one science unit, given the existing social and instruction norms of both teacher and students in a third-grade science class. It tells of the struggle the teacher went through in trying to use both oral and written discourse in new ways in order to promote student knowledge growth in science and the struggle that students went through as they were presented with this new way of thinking about science and writing. Included is a description of the teacher's gradual shift back to a more traditional way of teaching as she began to "fit" the ideas of conceptual change science teaching and writing-to-learn within her more familiar framework of exposing the students to ideas, finding out what they think, and telling them the scientific concept. Also included is an analysis of two students' writing in science and their perceptions of the ways in which this writing resembles or differs from other writing done in science across the year.

WRITING-TO-LEARN IN A CONCEPTUAL CHANGE SCIENCE UNIT[1]

Kathleen L. Peasley, Cheryl L. Rosaen, and Kathleen J. Roth[2]

Overview

According to the American Association for the Advancement of Science (1989), scientific literacy has emerged as a central goal in education. What has not yet been resolved, however, is how we are going to help our students develop the understandings of a scientifically literate individual. One possible tool for doing so is through the writing process. In response to this possibility, the Literacy in Science and Social Studies (LISSS) Project at Michigan State University was formed to study the ways in which oral and written discourse may be used as tools to help students understand the complex connections in science and social studies needed for literacy in these two areas. This collaborative inquiry uses four teachers whose roles and work schedules were restructured to give them time to study, deliberate, and design, implement, and assess changes in their teaching and in their students' learning. A research component of the project studies the ways in which this exemplary work context supports teacher change and the impact of teacher change on learners' understandings.

Initial research questions regarding teacher change studied teacher concepts and actions regarding (a) subject matter (e.g., the nature of the discipline, structure, and functions of subject matter content), (b) students as learners (implicit and explicit theories of learning), (c) the classroom community and social context, and (d) teaching for understanding (e.g., activities, tasks, representations, role of classroom discourse

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[1]A version of this paper was presented at the American Educational Research Association conference in April 1991 in Chicago.

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and writing, the nature of scaffolding for student learning and time needed, and selecting and organizing subject matter within and across subject matter areas).

This paper describes the role that writing-to-learn played in a third-grade science conceptual-change unit on reflected light. This is a story of how much change is possible in the course of one unit given the existing social and instructional norms of both teacher and students in a given classroom. Two perspectives were studied: those of the students, who had possibly never been asked to engage in writing as a learning strategy, and those of the teacher, who was just beginning to use writing-to-learn strategies in her teaching. Research questions examined (a) the conceptual change the students went through with respect to subject matter knowledge and the role that the writing played in helping or hindering this conceptual change, (b) the students' knowledge and skill regarding strategic use of writing in science, (c) the uncertainties the teacher experienced as she shifted the emphasis of her teaching from memorizing facts towards understanding broader concepts, (d) the effect that these uncertainties had on the students, and (e) what happened when there was a discrepancy between the teacher's and the students' perceptions of the purpose and audience for the writing tasks in science.

Part I. The Potential Role of Writing in Fostering Conceptual Change

Writing and Knowledge Construction

For over 25 years, science educators have debated over whether elementary school children should be taught science processes or science content. Many educators believe that young children first need to learn "scientific processes"--such as observation, classification, and description--which can then be transferred to any science content area. Others believe that content--often lists of scientific facts such as the formula for photosynthesis, or Newton's laws of motion--are necessary ingredients for students' ability to think scientifically or to "know" science.

More recently, however, educational researchers have begun to assert that the scientifically literate student is neither one who knows isolated science facts nor one who has mastered the processes of science. Rather, the scientifically literate student is one who is able to describe, explain, predict, and control real-world objects, systems, and phenomena with a power and precision impossible without an understanding of science (Anderson & Roth, 1990). In other words, the knowledge must be useful to the individual if it is to be of value. This assertion changes the question that science educators are struggling to answer. No longer is it a question of whether we should teach our students content or process or some combination thereof. The question has become, How can we best help students understand the complex connections and relationships in science necessary to enable them to use their knowledge to develop the descriptions, explanations, and predictions of a scientifically literate individual?

Over the last decade, there has been increasing attention paid to the role of writing in helping bring about such complex understandings in content areas in general. This attention resulted in the writing-across-the-curriculum movement that swept across both K-12 and college campuses through the '80s. As a result, the use of writing assignments to bring about understanding in the content area is often promoted as an effective teaching tool (Beyer & Brostoff, 1979; Calkins, 1986; Giroux, 1979; Langer & Applebee, 1987; VanNostrand, 1979).

It is hypothesized that good writing assignments can help students remember information and master broader concepts through writing about them. They can also help students master the skills and ways of thinking in a particular discipline. Good writing assignments can engage students in making connections between themselves and their subjects and in understanding the world in which they live (Brostoff, 1979). In other words, good writing assignments can bridge the gap between content and process in science. Writing can help students integrate knowledge in ways that help

them see the connections in the content they are learning, and writing can help them learn the ways of thinking and problem solving (the processes) in science.

In 1979, an entire issue of *Social Education* examined the role that writing can and should play in the content-area classroom. The general premise of the issue was that we learn as we write. As students write about a subject, they are forced to think actively about the subject. In doing so, they make connections and develop new insights about the subject they are writing on. Simply the act of writing about a subject helps students gain a new awareness of how otherwise isolated fragments of information about that subject relate to each other (Beyer & Brostoff, 1979; VanNostrand, 1979). At this point, however, little is known about the ways in which writing helps shape thinking. If teachers are to successfully help students use writing to connect fragments of information together, there is a need for more knowledge about writing in subject matter areas, science in particular.

Helping students make these connections and gain an understanding of how the fragments of information relate to each other is the power of writing in science and the first step in developing the explanations of a scientifically literate individual. Scientific knowledge is highly structured and organized. Isolated facts or processes are of little use for the complex function of description, explanation, prediction, and control which require the integration of multiple concepts (Anderson & Roth, 1989). Students need to understand the relationships among multiple ideas in order to carry out these processes with the power and precision of a scientifically literate person. The image of scientific knowledge as a web of multiple ideas connected to one another and that can be flexibly organized and reorganized in multiple ways is what Anderson and Roth (1989) call the structure of scientific knowledge.

It is hypothesized that carefully constructed writing tasks can help students understand the structure of scientific knowledge. Written work can serve as a concrete, visual record of scientific relationships that is easily accessible (Fulwiler,

1985) not only to the student but to others who may be part of the students' learning community. The writing acts, in some cases, such as concept maps, as a schematic summary of what was learned (Novak & Gowen, 1986). According to Staton (1980), this writing is also a vehicle for teachers to follow changes in students' thinking as they express their understanding of the concepts. As students are introduced to new concepts, they can add to or alter ideas in this visual record as their understanding grows. This enables students to more actively participate in their own learning than they may when receiving information through a more traditional teacher presentation. Britton, Burgess, Martin, McLeod, and Rosaen (1975) proposed that when students write as they think, they may engage in the kind of thinking that encourages exploration and discovery of ideas, although to date there has been little research done on writing-to-learn in science which would support this assertion.

Langer and Applebee (1987) argue that we have yet to develop an adequate research base for the argument that writing activities can significantly contribute to learning. There simply have been too few studies which address this question, perhaps none in science. However, there is tremendous potential for writing in science as a tool to help students make flexible connections among multiple ideas and to develop the explanations of a scientifically literate individual.

Definition of "Writing-to-Learn"

The studies on content-area writing done to date tend to define writing in several ways. For purposes of this study, writing was broadly defined as language choice on paper (from Mayer, Lester, & Pradl, 1983). This includes not only writing of a paragraph or longer, but also such activities as notetaking, drawing, and diagraming. Regurgitive practices, such as fill-in-the-blank, and low-level recall activities barely fall into this definition since they offer limited language choice. And copying, which does not involve any active language choice by the students, would not be considered writing according to this definition. Although some teachers and researchers might

argue against including some of the shorter forms of writing (i.e., drawing a diagram or fill in the blank), these are included because the writing in science often closely connects to the classroom discourse. Therefore, it could be argued that thinking doesn't begin and end with writing. Rather, writing is part of a larger discourse community that includes class discussion, laboratory activities, and group work. The shorter forms of writing, such as short answer, may only serve as a starting point or a midpoint for developing an idea through oral discourse. In addition, this definition is compatible with the way content-area teachers and students define writing. Applebee (1981) found, for example, that a teacher might describe a class as being "full of writing" when in fact this often meant writing one-sentence answers to study questions.

According to this broad definition, nearly half the time in current *secondary* science class is spent on writing. However, nearly all of this time is evenly divided between the more mechanical or regurgitive forms of writing described above. Most typically, writing in science is short-answer responses to study sheets, often in the context of laboratory work. Applebee (1981) found that none of the time in science class was spent writing summaries, writing analyses of ideas, or using writing to help develop connections and build theories. Homework assignments in science tended toward "read and study" assignments. These results agree with the study done by Clark and Florio (1982) which describes the many missed opportunities for writing in the content-area class.

There appears to be even less writing of any length done in science at the elementary level, although there has been considerably less research directed to writing in the content area at this level. A search of the ERIC and CIJE data bases for the last five years revealed a total of 11 articles on the uses of writing in science in the elementary classroom. Of these 11 articles, the majority tended to place the emphasis on the writing process rather than on using writing as a tool for making connections and identifying relationships in science, and none explicitly address the role that

writing can and should play in shaping thinking in science. Although using writing assignments is often promoted as a valuable form of instructional discourse and an effective teaching tool (Calkins, 1986; Langer & Applebee, 1987), writing is incorporated into most elementary science texts, and therefore most science classes, in only a token fashion (Rosaen, 1989).

Purpose of Content-Area Writing

Other researchers have found that although considerable writing occurs in the elementary content-area classroom, most of the writing is for the purpose of "knowledge telling" or evaluation rather than for developing new knowledge or new understandings (Beyer & Brostoff, 1979; Calkins, 1986; Rosaen, 1989; Rosaen, 1991). Many teachers *assume* that any writing promotes learning, when, in fact, some writing assignments impede learning because of their structure (Rosaen 1989, 1990). It is further argued that increased opportunity to write about subject matter does not necessarily lead to improved opportunity to think about subject matter in and of itself (Rosaen, 1990).

Alternatively, many teachers simply fail to realize that writing in their subjects might contribute to subject matter learning as well as improve writing skills (Applebee, 1981), and so they tend to focus more on writing than on content, even when writing about subject matter. This approach directly conflicts with the view of Giroux (1979) who sees writing not as a subject nor as a skill but rather as a *process that can be used to learn a subject.* Giroux is emphatic about the need to wed writing and subject matter learning and to view writing as a learning tool.

It is important to note, however, that elementary teachers often feel overburdened already with the sheer enormity of their task. They do not have room in the curriculum to add anything new. Therefore, the challenge for researchers is to create *better* writing opportunities by changing the purpose of the writing rather than create *more* (Calkins, 1986; Rosaen, 1990).

Through their research in secondary content area classrooms, Langer and Applebee (1987) were able to define three essentially heuristic categories for defining the purpose of writing in content-area classrooms. These three categories serve as a useful way for researchers and teachers to organize their thinking about the type of writing that is typical in an elementary science classroom, as well as the type of writing that is desirable in this classroom. These categories are also important for the students. Clark and Florio (1982) found that understanding purpose of a writing assignment was a crucial part of a successful occasion for writing. Therefore, the purpose of each writing assignment needs to be made explicit to the student if it is to result in a meaningful writing occasion. The three categories developed by Langer and Applebee (1987) are

1. Writing to draw on relevant knowledge
2. Writing to consolidate new information
3. Writing to reformulate and extend knowledge

Writing to draw on relevant knowledge includes preparatory questions to frame upcoming studies. Often in science this is done to draw out students' prior or naive conceptions about real-world phenomena, which researchers have shown is a critical component of conceptual change teaching (Anderson & Roth, 1989). For students to change their stories, they need a record of what they originally thought. Writing to consolidate new information reviews and reinforces new material. This emphasizes the synthesis of content rather than the opinions expressed when writing to draw on relevant knowledge. Posner, Strike, Hewson, and Gerzog (1982) refer to this as the development and understanding of plausible, fruitful, alternative concepts. A concept map exemplifies writing to consolidate new information. According to Novak and Gowen (1986), concept maps provide a "visual road map" which shows some of the pathways taken to connect meanings of concepts together. Novak and Gowen also report that students remark that they recognize new relationships and hence new

meanings by constructing a concept map. Therefore, concept maps could also represent a form of writing to reformulate and extend knowledge since this involves exploring relationships among concepts through writing about them. Writing for the purpose of extending and reformulating knowledge emphasizes greater concern with the *structure* and *relationships* among ideas. The student who is able to organize and reorganize knowledge flexibly and use it to describe, explain, predict, and control real world events would be considered scientifically literate.

The first of Langer and Applebee's categories, writing to draw on prior knowledge, falls into what Britton et al. (1975) describe as the writing function category of *expressive* in which the students are "thinking out loud on paper." This is intended for the author's own use and could only be understood by someone who shared the writers' context. The purpose of this category is to get ideas out in the open, not to determine the "correctness" or scientific validity of the ideas.

Langer and Applebee's other two categories, writing to consolidate and writing to extend and reformulate, resemble the *transactional* function category of Britton et al. (1975). In some instances of transactional writing, the purpose of the writing is to "record facts, explain and explore ideas, and to construct theories" (p. 88). Unlike more poetic forms of writing, the attention to the forms of the language is incidental to understanding and will often be of secondary concern. The purpose of the writing is exploratory and tentative and emphasizes using the writing to explore ideas rather than using the written form. Calkins (1991) describes this process as learning to think on paper. She quotes William Stafford saying, "If I put something down, that thing will help the next thing come, and I'm off. If I let the process go on, things will occur to me that were not at all in my mind when I started" (p. 128). Calkins describes the interior dialogue that goes on in a writer's head as he or she works to understand as less an evaluative dialogue than more an articulation of things such as, "That also makes me think..." and, "But how does that relate to...?"

To these categories Britton et al. have added a series of special categories which do not constitute writing-to-learn occasions but which often typify school writing tasks. *Pseudo-informative* writing superficially appears to be normal transactional writing, but beneath "the apparent transaction there lies another, that of showing the teacher that what he has taught has been learned" (p. 104). In this situation, the writer has concentrated on satisfying the teacher as evaluator at the expense of writing for his or her own educative purpose. This agrees with Applebee (1981) who found that most high school writing was executed for the purpose of displaying knowledge. Scardamalia and Bereiter (1986) call this a knowledge-telling function and argue that writing carried out using this strategy is not a very powerful tool for developing understanding.

Another of these categories, *dummy run*, occurs when a teacher requires a student to perform a writing task as practice or to demonstrate that he or she is capable of performing this type of task. A typical dummy-run task in science is writing laboratory reports in a rigid format. The purpose of these reports is often to demonstrate that the form has been mastered rather than to use the form as a tool to explore, elaborate, extend, or process the knowledge learned.

When developing writing-to-learn activities for elementary science, it is crucial that care is exercised that the writing tasks are not only planned but also framed for the students in such a way that they do not fall into these more traditional school-oriented writing categories. Emphasizing displaying knowledge of the written form (dummy run) or of the science content (pseudo-informative) results in undeveloped new understandings of the content under study. Scardamalia and Bereiter (1986) point out that not only are these forms of writing not very powerful tools for developing understanding, but that as long as students follow a knowledge-telling strategy they will never become successful writers.

Audience for Content-Area Writing

Pseudo-informative writing, in which the students perceive the teacher as an evaluator of their writing, introduces the question of audience. Every piece of writing is shaped not only by its function but also by a concept of the audience to whom it is addressed (Eco, 1979; Mead, 1934). Virtually all school writing has only one audience, the teacher (Applebee, 1981). Therefore, unless otherwise indicated, students tend to assume the audience is teacher as evaluator, which strongly influences their writing. Even in elementary school, students are very conscious of the need to please the teacher (Clark & Florio, 1982). Researchers have found that when audiences other than the teacher exist, both the involvement with the writing task and the quality of the writing that results improve noticeably (Martin, D'Ary, Newton, & Parker, 1976). However, ambiguity about the intended audience often produces a mixed response from the students. Most students will tend to assume the audience is teacher as evaluator and often focus on spelling, punctuation, and so forth. Some students will assume the writing is for self and will be more reflective. Still other students, out of frustration, may write nothing until a clearer guide to the intended audience is given (Clark & Florio, 1982). For these reasons, it is important to either make explicit to the student the intended audience, particularly if it is other than the teacher as evaluator, or to provide occasions for students to identify their own audience.

One possible explanation for the improved quality of writing seen when the audience is other than the teacher as evaluator is that writing for the teacher as evaluator often produces a sense of pointlessness. Students feel that they are repeating what the audience already knows, therefore they show little involvement or sense of purpose (Applebee, 1981). Thus the categorizing of this type of writing as pseudo-informative by Britton et al. (1975).

By contrast, transactional writing addressed to wider audiences usually involves more naturally motivated tasks, where there are new pieces of information or new experiences to convey to someone who does not already know about them (Applebee, 1981). Table 1 summarizes the relationships both among these different categories and audiences for writing and their relationship to conceptual change learning in science.

Genuine writing-to-learn occasions in science require both teacher and students to negotiate and agree upon the purpose and audience for the writing task since these factors strongly influence the writing a student does. Ideally, the purpose of the writing would not resemble the more typical pseudo-informative or dummy-run functions described by Britton et al. Ideally, the purpose would be in one of Langer and Applebee's (1987) three categories since they have shown that these three types of writing help shape student thinking in subject matter areas. Additionally, these three categories nicely parallel the categories necessary for conceptual-change teaching in science developed by Anderson and Roth (1989) and Roth (1985). Unfortunately, there has been very little research done on the role of writing in shaping thinking in science, possibly none at the elementary level. Therefore, a number of questions need to be answered before writing-to-learn can achieve its full potential in the elementary science classroom.

Given the typical norms for classroom writing, do students perceive the writing-to-learn task in the same way the teacher intended? And if not, why not? What needs to occur before teachers and students do reach agreement? If there isn't agreement between the teacher's and the students' perceptions, does this influence the effectiveness of writing in shaping students' thinking in science? In what ways? These are just a few of the questions that need to be addressed when considering using writing-to-learn in science.

Table 1

Summary of Categories of Writing Audience and Function

Audience	Langer & Applebee	Britton et al.	Scardamalia & Bereiter
More than the teacher	Draw on relevant knowledge	Expressive	
More than the teacher	Consolidate & review knowledge	Transactional	
More than the teacher	Extend and reformulate knowledge	Transactional	
Teacher as evaluator		Pseudo-informative	Knowledge telling
Teacher as evaluator		Dummy-run	Knowledge telling

Part II. The Case of Jane and the Science Unit

History of the Unit

A classroom teacher, "Jane,"[3] and MSU researchers collaborated on developing a single conceptual change science unit on light during the winter semester. Jane typically taught a unit on phases of the moon in the spring, in which the students learned the names of the different phases, and she originally intended that this be the focus of the unit. In past years, Jane had told the students that the moon is not a source of light but rather reflects light from the sun, and went on to teach about the phases of the moon. In order to understand phases of the moon, students must first understand this. However, after viewing videotapes and reading about students' naive conceptions about the role of light in seeing (Ramadas & Driver, 1989), Jane realized that students have many naive concepts about light that may not alter simply by her *telling* them the moon is not a light source. She became aware that these naive concepts must be addressed throughout instruction as the students struggle to develop a deep conceptual understanding of why we see different phases of the moon. Therefore, she decided that light would be the basis of a unit being collaboratively developed, followed by a unit on phases of the moon.

Role of Writing in the Unit

During the fall and winter, LISSS Project members had studied the role writing-to-learn might play in bringing about subject matter understanding. Jane was extremely interested in and excited about possibly using writing in this manner and decided to incorporate writing into her unit in the form of a science journal. It is important to note that in the past the only time that Jane used writing in science class was to evaluate student learning (pseudo-informative writing or knowledge telling). Therefore, science journals represented a way not only to change the purpose and

[3]Names of the teacher and students here are pseudonyms.

audience of the science writing but also an attempt to change the norms for classroom writing that existed in Jane's science class.

The writing was intended to mirror classroom activities rather than stand alone as an isolated activity. The goal was that students would see writing not as a final form, as in writing for evaluation, but as a temporary form of ideas that could be revisited and changed as their thinking changed. The writing would continue the discussion begun in class and, like discussion, could function as a way for students to explore their ideas. Therefore, rather than write for the teacher as evaluator, the most common audience in this classroom, writing activities were designed so that the students would write for themselves, their peers, or for the teacher as part of an ongoing dialogue (categories from Applebee, 1981). And rather than write for evaluation, as was typically done, the activities were designed to elicit students' prior knowledge, consolidate and review knowledge, and extend and reformulate new knowledge (categories from Langer and Applebee, 1987). Appendix A includes sample writing activities from the light unit.

Typically in science class, teachers ask a lot of questions (Staton, 1980), encouraging procedural display (Roth, 1987) or knowledge telling (Scardamalia & Bereiter, 1986) by the student, who relies on a few big words. However, students often don't get a chance to ask any questions in return and almost never have time to ask clarifying questions to find out what they don't understand (Staton, 1980), which is a critical component in conceptual-change learning. Therefore, it was decided to give students opportunities to explore their knowledge in writing by regularly asking questions about light in their journal. As asking questions represents another approach to exploring ideas in writing by emphasizing the question rather than the form, this too could be considered a type of transactional writing.

Journal writing also benefits further class discussion (Fulwiler, 1980) since it is a concrete reference for student thinking. Therefore, it was planned that there would

be times when the students would be asked to either share what they had written or to look at what they had written when discussing a question posed in class.

The classroom norms for writing and instruction in science were to differ from the journal writing norms that had been established in this classroom. The science journals represented a departure from the writing typically done in Jane's science class--knowledge telling with she as evaluator In addition, the vast majority of school writing even by the third grade is for this same purpose and audience. Therefore, for journal writing to succeed as a writing-to-learn occasion, the norms needed to change. In order to help the students make this change, the purpose of and audience for each writing assignment was to be made explicit not only through oral directions given by Jane but also through extended discourse about the role that writing would play in the unit and how it might differ from other writing that the students had done either that year or in previous years. The importance of this explicitness prevails throughout the literature on writing (Rosaen, 1990).

Social Aspects of the Writing

In addition, although social mediation of learning was not an explicit component of this study, some of the writing activities included group-written products or group discussion of individually written products in which the primary audience was a subset of classroom peers in a slightly different context than perhaps the traditional audience of peers. This emphasis on the social aspects of writing was part of the effort to develop the social and instructional norms necessary for a successful writing-to-learn occasion. The goal was for the students to use writing not as an individualized activity for sharing ideas in their final form to the teacher as evaluator but rather as another context for exploring ideas, as a natural extension of the ideas that had been examined during the class discussion or in discussion with a subset of their peers. And rather than being personal and private, these ideas were to be public and shared

while the students worked as a community towards understanding the scientific concepts.

Data Collection Procedures for Jane

During this initial unit planning period, Jane's thinking about the content and writing and about conceptual-change teaching was documented on audiotape, which also served to record the way in which she intended the writing be used by the students. And, in addition to regular unit-planning meetings with MSU researchers, Jane's unit was discussed in the larger study group involving all four of the project teachers, the two MSU researchers, and the three MSU graduate assistants. These discussions about the unit were also audiotaped. Field notes of the unit planning meetings and these study group discussions provided additional documentation.

Researchers also conducted interviews with Jane at four different times during the year, from early fall through June, to document the changes in her thinking about teaching and learning across the year. Across the year, these interviews probed the way in which she used curriculum materials, including science activities, how she evaluated student learning, and her goals for her students' learning, enabling documentation of changes in these areas over time.

Summary of Unit Planning Data

Analysis of these interviews as well as the transcripts and field notes from the unit-planning meetings revealed that there were two levels of conceptual change occurring during the unit development and teaching. While Jane was developing and teaching a unit for conceptual change for her students, she was also going through a period of conceptual change as a teacher in which she reexamined the ways in which she had always thought about and taught science. This reexamination led her to the painful realization that her students were possibly not always learning the content in the ways in which she intended and assumed they were learning it. A particularly important moment in her conceptual change occurred when she saw a videotape in

which "good" high school students as well as Harvard graduates reveal their own misconceptions about the seasons and how they are related to the earth's movement around the sun. It was after viewing this that Jane shifted from saying things like, "I think they understand if you just *tell* them clearly," to saying things like, "You can't make any assumptions about what they know." She also began to talk about the importance of starting with the students' own theories or stories so that instruction can begin where the student is at and work towards helping the student understand the differences between his or her story and the scientific concept.

Summary of Unit Teaching Data

Once Jane finished planning and began the actual teaching of the light unit, her enacted plans were documented through the use of audio- and videotaping and field notes which focused in particular on the way in which she framed the writing tasks and the way in which she responded to student questions about both the subject matter and the writing.

Analysis of these classroom observations revealed Jane's difficulties in three areas. First, although the writing assignments were intended to be written for a variety of different audiences and purposes, the way in which Jane implemented these tasks subtly altered either the originally intended audience or purpose in many cases. In other cases, although Jane clearly verbally outlined the intended audience and purpose for the writing (again reverting to the norm of "teacher as telling"), the classroom norms for writing were such that there was a literal miss among what she intended, what was enacted, and what the students perceived.

A second area of difficulty arose from the subject matter itself, and Jane's struggles represent an interesting case. Unlike many elementary teachers, Jane liked teaching science and described herself as feeling comfortable with science education. However, even though she had a strong science background and had always considered herself a science teacher (having taught middle school science prior to

becoming the third-grade team's science teacher), she struggled with many uncertainties as she worked to shift her teaching away from a combination of facts and hands-on exposure to one of teaching for conceptual understanding. While teaching, she often seemed somewhat confused and frustrated, wondering where to go next, and after class would often comment on how much more difficult it was to teach this way. In particular, she realized she didn't always know how to address the naive conceptions she was uncovering through discussion and writing. She said she felt much more comfortable just giving them the information and recognized that often after she uncovered students' conceptions she would revert to *telling* them how they were wrong and *giving* them the scientific concept.

A third area of difficulty centered around classroom norms. As will be seen, the classroom norms for discussion and writing in science were already firmly established by the time the unit was taught in late spring. The result was that there was active resistance on the part of her students to suddenly change the way in which they used discussion and follow-up writing in science. The result of these struggles--the uncertainty experienced by Jane and the resistance to change experienced by her students--was that although Jane did change many aspects of her teaching, as the unit progressed she worked these changes into a familiar framework with which both she and the students were more comfortable. In this respect, Jane didn't really seem to have so much a new concept of teaching science as some new strategies that she plugged into the same concept. Indeed, by the end of the unit, although Jane was doing and saying many of the things recommended by conceptual change and writing-to-learn advocates, the *way* in which she enacted her intentions subtly shifted them away from teaching for understanding.

Although Jane had always used many hands-on activities in her teaching in past years, they tended to be isolated, neat activities often recommended by the teachers manual, and done for the sake of doing an activity that got the students

excited and involved. There is often an implicit belief in doing activities in science as if they have some value in and of themselves, and this seemed to be Jane's justification for doing activities. She talked in early interviews about the value of the activities in getting the students actively involved in doing science and the importance of exposing them to many new ideas. While it is agreed that this is important, she apparently did not focus on other ways in which a hands-on an activity can be used so that it goes beyond just exposing students to new ideas and generates excitement about science by getting them genuinely thinking about, or puzzling over, the content.

Puzzling over ideas was the intent of the light unit, which would focus on the central question, "How does light help us see?" Its activities, including writing, were designed to help the students puzzle over, or use, the ideas of the unit in ways that helped them describe, predict, and explain everyday phenomenon. In this respect, unit focus differed from any other that Jane had taught that year. It was also unique with respect to the role that writing was designed to play in helping the students make connections and think about the unit concepts: to elicit prior knowledge, consolidate and review knowledge, and extend and reformulate knowledge (Langer & Applebee, 1986).

However, as with the discussion and follow-up writing, the way in which Jane used the activities in the unit tended to shift the emphasis away from teaching for understanding and toward the more comfortable and familiar framework of just doing activities. As the unit progressed, the activities, which were carefully designed to get the students puzzling over the ideas, became isolated from the unit content. There were several indications, which became more pronounced as the unit progressed, that this shift had occurred. First, there was increasingly less discussion before the activity to give the students a sense of why it was being done and what they might use the activity to help them figure out. Second, the activities were presented to the students as extremely structured, with step-by-step directions that could be followed without any

real understanding of why each step was being done. Finally, by the end of the unit, the discussion following the activity consisted of finding out the data that the students had collected and *telling* them what they "should have found out."

At the end of the year, however, Jane had a different perception than the reseachers of the differences between the light unit and other units she had taught that year. Rather than focus on the goal of getting students to make flexible and useful connections and on the ways in which the activities were used to promote understanding, she talked about its uniqueness in different terms. She had not used the book to plan or to teach. She used science journals and so used writing in different ways. She had planned the entire unit in advance, rather than day to day as was more typical. Although Jane saw the unit as different from other units that she had taught previously, she perceived different changes than did the researchers. While the researchers emphasized and noticed differences in what was intended with the unit, Jane's perceptions focused on and accurately reflected the enacted unit. The next question to be addressed was whether Jane's students saw the unit as different from or the same as prior units and in what ways and to address the implications for their learning.

Before discussing student perceptions of the unit, it should be pointed out that one problem with the unit was that it was overly ambitious with respect to time, given that the unit teaching began one month before the school year ended, that there are many interruptions in instruction in the spring for fieldtrips and special year-end activities, and that only one-half hour, four afternoons a week was devoted to science (which frequently turned into about 20 minutes). In addition, Jane had underestimated the amount of time that would be necessary for procedural details such as passing out and collecting the science journals, and giving instructions for the writing task. The result was that only six writing tasks were actually used in the unit--two to elicit prior knowledge, two to consolidate and review, and two to extend and reformulate. Yet this

amount of writing is still a significant increase over the amount of writing in Jane's previous science teaching.

Data Collection Procedures for the Target Students

Two target students were selected as the focus of this case study. Jane was asked to select two students, one boy and one girl, who represented average students in terms of ability in science. To provide some possibly interesting contrasts, however, one of these students was to be what Jane considered a "teacher pleaser" who tried hard to do exactly what she wanted, while the other was to be more of a nonconformist who was less concerned with pleasing her and more concerned with simply doing the task. Julie was selected as the "teacher pleaser" while John was selected as the "nonconformist."

As the writing task was introduced, field notes focused on documenting the types of questions that these two students asked prior to and during the writing. In addition, each of these two students was observed on an alternating basis as they went about doing the writing task. They were then interviewed immediately upon completing the task, with the writing still in front of them to serve as a concrete basis for the interview (see Appendix B for interview protocol). This interview focused on their perceptions of the audience and purpose for the writing. Effort was also made to ensure that the tasks that the two students were interviewed on were as similar as possible (i.e., written for the same purpose and to the same audience) so that comparisons could be made between the two students.

Samples of all of their writing was collected, and examination of the writing, combined with the information given during the interview and field note data, was used to make some assertions regarding whether their perceptions of audience and purpose for the writing task agreed with Jane's intended and/or enacted audience and purpose for each task (Appendix C details the analysis procedure). Table 2

summarizes Jane's intended and enacted purpose and audience for each assignment and the students' perception of the purpose and audience for each assignment.

Journal Writing--Day One

The writing task the first day of the unit was a task intended by Jane to elicit students' prior knowledge as they wrote for the audience of self and teacher as part of an ongoing instructional dialogue. The students were verbally given the following instructions for the writing task, which was to be done on the first page of their journals:

> Make a list of things you already know about light
> Include questions that you have about light
> May want to include a picture about how you think light helps you see
> Reread the list and put stars by things you are sure of
> Reread the list and put question marks by things you are unsure of

The directions to include questions that they have about light is consistent with Staton's (1980) assertion that journal writing should provide students with opportunities to ask questions of the teacher. As she gave the instructions for this activity Jane emphsized to the students that at this point there were no right or wrong answers and that she would not grade their journals, although she might write back to them in the journal. She emphasized to them that she was interested in what they were thinking and she wanted them to get their ideas on paper so that they had a record they could go back to later. Therefore, Jane explicitly stated the intended purpose of eliciting prior knowledge for the audience of both self and teacher as part of an ongoing dialogue.

The Cases of Julie and John

The interview with Julie revealed that she had very different perceptions of the purpose and audience for the writing task than Jane had intended. At this point Julie operated within the strongly established norm of seeing all writing as "final form," written for Jane as teacher-evaluator. When Jane said that she would not grade the

Table 2

Summary of Intended, Enacted, and Perceived Audience and Purpose for the Writing[a]

	Intended		Enacted		Perceived	
	Purpose	Audience	Purpose	Audience	Purpose	Audience
Julie	Elicit prior knowledge	Self & teacher dialogue	Elicit prior knowledge	Teacher dialogue	Unclear	Teacher as evaluator
Julie	Consolidate & review	Self & peers	Unclear	Self	Consolidate & review	Unclear
Julie	Extend & reformulate	Teacher as evaluator				
John	Elicit prior Knowledge	Self, teacher dialogue	Elicit prior knowledge	Unclear	Unclear	No clear audience
John	Consolidate & review	Teacher as evaluator	Knowledge display	Teacher as evaluator	Unclear	No clear audience
John	Extend & reformulate					

[a]Empty cells represent missing data points.

May 7, 1990 Light

Light might come from the sun. Light might come from light

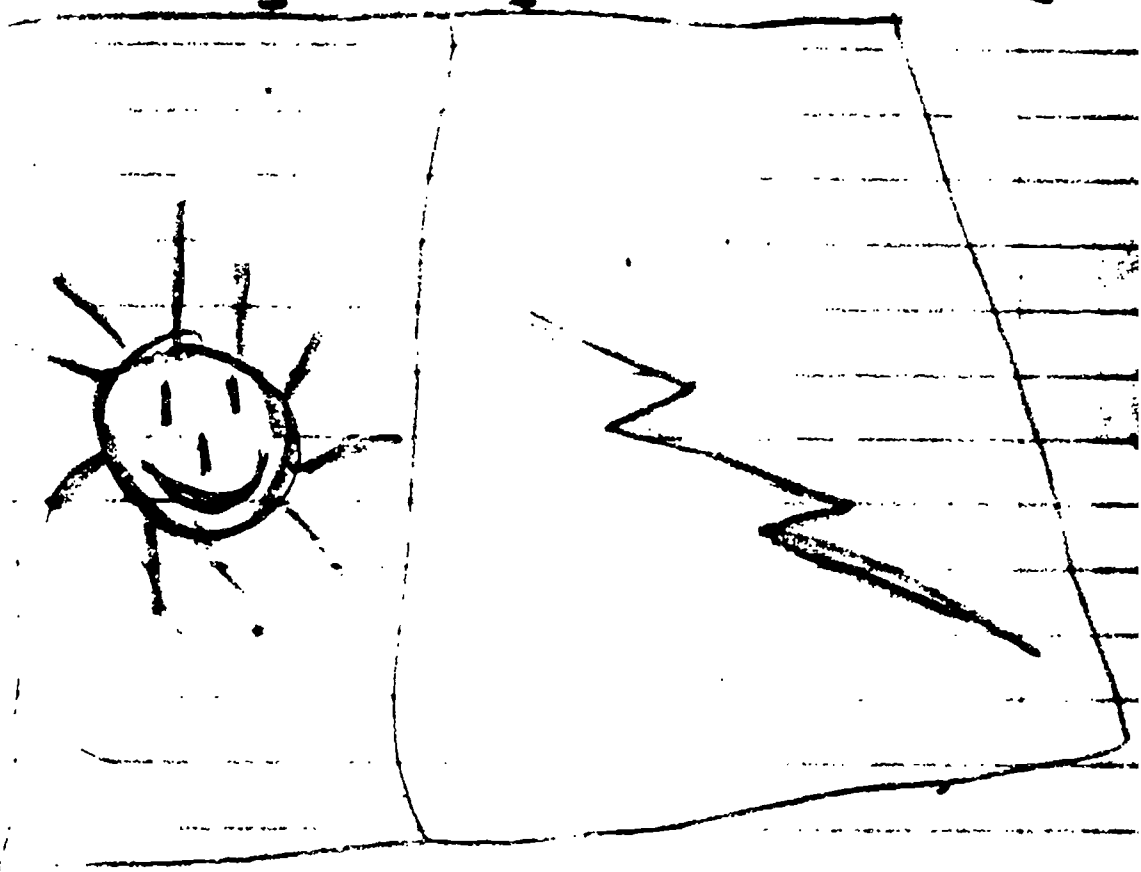


Figure 1. Julie's first journal entry.

journals that day, Julie took that to literally mean that she would not grade the journals on that particular day, but would grade the journal entry done that day at a later date.

In looking at Julie's first journal entry, Figure 1, the idea of writing for teacher as evaluator comes through clearly. In general, Julie very carefully followed Jane's directions. She listed things she already knew about light, drew a picture of those two things--a sun and a lightening bolt, although they didn't add anything new to what she had written--and she put stars by each of her ideas. The fact that she put stars by these ideas rather than question marks may reflect her belief that she knows everything about light, but may also reflect her unwillingness to admit to the teacher-evaluator that she is anything less than confident about the correctness of her ideas. Her word choice in both statements, however, belies her proported confidence in her knowledge. In both statements she uses the word "might" saying, "Light *might* come from the sun," and "light *might* come from lightening." She also chose not to write any questions that she had about light, which was the one teacher direction that she did not follow exactly. Again, from her perspective of writing for teacher as evaluator, writing a question might point out the tentative nature of her thinking, and this is typically not done in school writing for an evaluator.

Another indication that Julie viewed this writing task as typical school writing for teacher as evaluator is that she wrote enough to feel she had satisfactorily answered the question but did not write a lot, especially considering that in the interview she stated that she already knew "everything about light" and so this task was "boring." Rather than being naturally motivated by curiosity to puzzle over her knowledge in writing, as was Jane's hope, Julie wrote what she was asked to write in order to complete a school task.

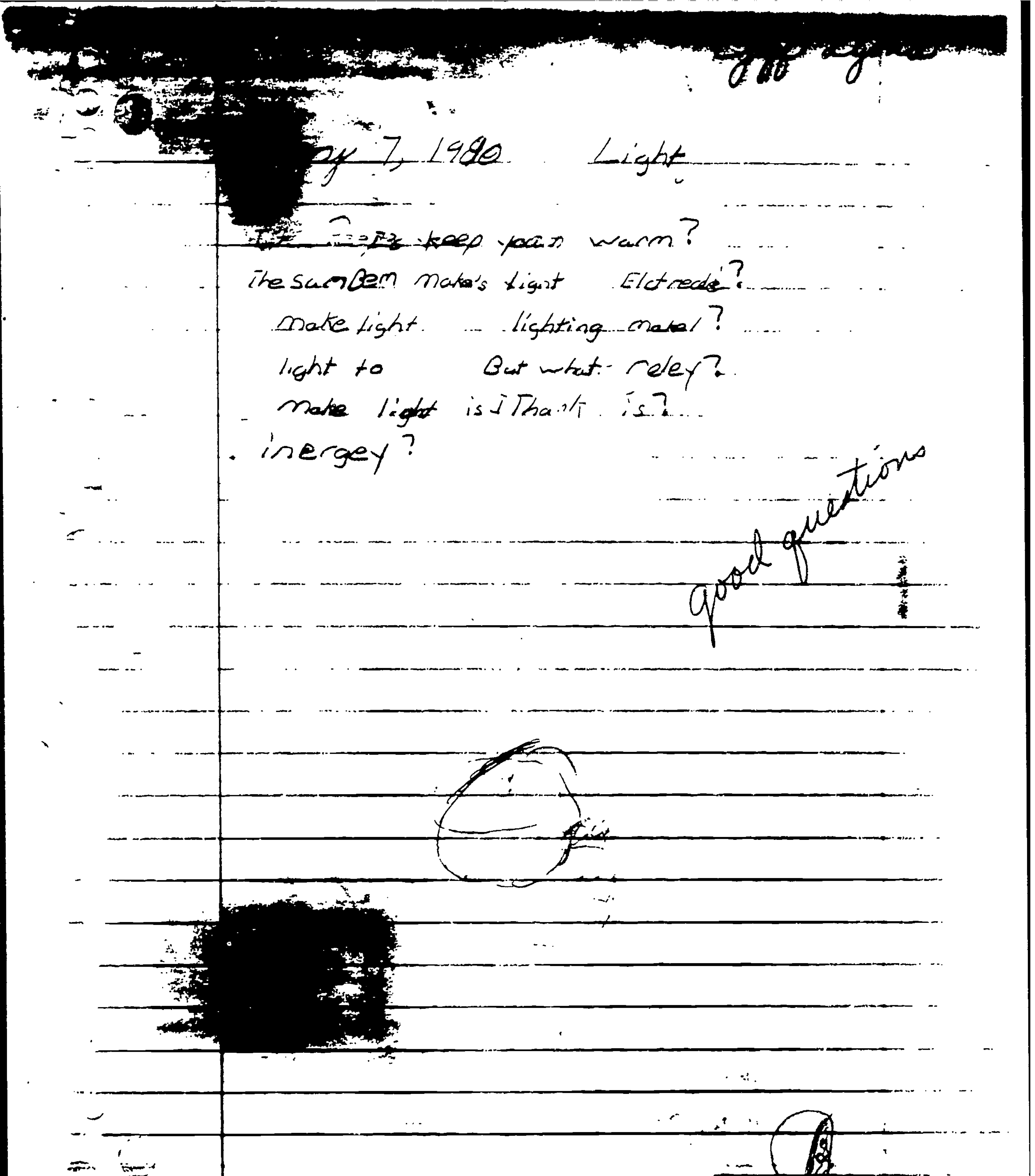
This task was intended to elicit prior knowledge and also to get the students thinking about their knowledge about light. In this respect, it was intended to "establish the problem" or to create dissatisfaction with their existing knowledge, an important

piece of teaching for conceptual change. However, for Julie, there was no admission of any problem; as she said in the interview, "This was boring because I already knew everything about light." For Julie, the way in which the question for the journal writing was framed did not establish the problem. She saw nothing problematic or conflicting in her thinking and so to her this was a "boring," empty exercise consisting of telling the teacher everything she already knew about light.

Part of the problem with the framing of the task may have been that it was isolated. Jane had hoped that simply by asking the students to write their ideas and by reassuring them that there were no right or wrong answers, they would be naturally motivated to puzzle over the question in writing, something they had never been asked to do before. In retrospect, given the strong norms for school writing that emerged through the course of the unit, this was an unrealistic expectation. In this instance, the writing needed to be more connected to either a class or small group discussion, which may have served a starting point for thinking that could then be continued through the writing.

John's perception of the writing on this same task contrasts with Julie's in some interesting ways. When the writing task was assigned, the first question he asked was, "Will there be any rights or wrongs?" Jane responded that there would not be any wrong answers; she was only interested in their thinking. This seemed to satisfy John that this was the same as any other nontest writing they had done. As he stated in a later interview, "It doesn't matter what we write as long as we write something." He went on to describe writing in terms of "busywork."

In contrast to Julie, John seems to have approached the writing task differently (Figure 2, his first journal entry). John seemed comfortable with putting question marks by his ideas and didn't appear to feel obligated to be confident about his ideas. He also used this first writing task as more of a true writing-to-learn task. He appeared to be puzzling through his ideas as he began with statements about what he knew: "It



...y 7, 1980 Light

[illegible] keep you warm?

The sunBem make's light Eldtrede?

make light ... lighting matel?

light to But what reley?

make light is I Thank is?

inergey?

good questions

Figure 2. John's first journal entry.

keeps keep you warm?" "The sunBem make's light," "Elctrecty? make light," "lighting makes? light to"; and then went on to raise some questions: "But what reley? make light," "is [it what] I Thank [it] is?" "inergey?"

Unlike Julie who put stars by each of her two ideas, John put question marks by his. However, he too seemed to follow a school norm for writing with the placement of his question marks. Rather than putting them after each idea, he placed question marks at the end of each line, regardless of whether the idea ended at that point. The result is that it would appear that rather than rereading his ideas to decide which ones he felt he really understood and which ones he wasn't sure of, he simply added question marks. This may have reinforced his belief that writing in science is busywork since he followed the teacher's directions, but in an apparently mindless fashion which doesn't achieve the purpose Jane intended. Indeed, when asked in an interview what he thought was the purpose of his writing, he never gave a clear purpose other than the generic, "To help us learn." He was unable to articulate beyond this as to how the particular writing assignment might help him learn or what specifically he might learn from the writing. Rather, he believed that things were done in school to somehow help him learn, but he never questioned how they might be doing so.

When asked who would be reading his writing, John didn't have a clear sense of audience. He definitely knew that it was not teacher as evaluator, unless it was on a test, but he couldn't replace that audience with any other. He said that he would not read what he wrote and that he would not share it with anyone else. Again, this lack of a clear audience may have reinforced his belief that the writing was simply busywork.

The second assignment that Julie was interviewed about was designed to consolidate and review information learned in a laboratory experiment. In the experiment, students shone a flashlight on a piece of cardboard with a pinhole in it and decided whether all the light went through the hole and if not, where the extra light went. This was designed to have them think over the idea that light cannot bend or go

around corners but will bounce off of any object it hits. Jane intended that they share their ideas with two other students after they wrote about them. When the writing assignment was given, no clear purpose or audience was communicated to the students. Instead, they were given two questions: (1) Did all the light go through the hole? and (2) If not, where did some of it go? They were told to answer either "Yes, it all went through the hole" or "No, it didn't all go through the hole," and then to tell where the extra went if it didn't go through the hole. They were told that they were writing this down so that they could go back later and see how their ideas had changed; therefore the enacted audience was self. It was only after they had completed the writing task that Jane told them that they would be sharing their answers with two partners.

A third question that they were to respond to was from a second activity that they had done in which they used a long ribbon to model light bouncing off of objects and traveling to other objects. Question number three asked the students to tell how much ribbon would be needed to show how far a single beam of light could travel. They were told that they just needed to put down a number and a unit; i.e., feet or rolls of ribbon. They were not asked to explain their answer.

With two of these three questions, Jane began to fall back into ways of teaching that were more familiar to both her and her students. Questions number one and three were one-word answers--either yes or no for number one with no explanation of why, and an almost randomly selected number for question three since the students didn't really have any basis for choosing a number (the concept that Jane was looking for was infinity, or a very large amount of ribbon). As with the first writing assignment, there was little discourse surrounding the activity before the writing took place. If there had been some discussion of the activity in advance of the writing, including some teacher-scaffolded support of their ideas about the experiment, the students may have had more of a basis for answering the questions and explaining their answers that

would have made this less of a typical school task and more of a writing-to-learn occasion. Question number two was closer to a writing-to-learn task since students were asked to think about and write what happened to the extra light that didn't go through the hole.

Although this writing task took place 10 days into the unit, Julie persisted in viewing the teacher as evaluator as the audience for her writing. However, by this time she had decided that the teacher didn't care what she wrote and so she didn't care either. This is not an unreasonable interpretation given the lack of interaction that Julie had with Jane. At this point in the unit, Jane had not yet read and commented in the journals. As with John on the earlier task, Julie seemed to realize on some level that the audience for her writing was not teacher as evaluator because the writing had not been evaluated. However, she clung to this as the only possible audience which resulted in increasing frustration on her part, resulting in her belief that the teacher didn't care what she wrote and therefore she didn't care either. In Julie's words, "It doesn't matter; nothing matters."

John continued to believe that there was no real audience and that the purpose for the writing was to help them learn, but continued to be unable to articulate how or what it helped him learn. In each interview he was asked why he thought Jane had them do the writing task to which his response was always, "To help us learn." However, when asked how the particular writing task might help them learn, or what it helped him to learn he responded that he didn't know, it hadn't helped him learn anything new. At the same time, however, pre- and posttest data shows that there was a shift in John's thinking. By the end of the unit he was able to diagram and to explain, both orally and in writing, how light traveling from a source would hit an object, bounce off the object, and travel to a person's eye, which allowed him or her to see the object. This contrasts with his preunit conception that you see objects by your eye looking at the object.

Field notes show that John often participated in the class discussion. It is possible that for him the writing consolidated and reviewed ideas from these class discussions. However, because he still believed in the norm for school writing in which writing is an isolated activity done primarily to show the teacher-evaluator what you know, John may not have explicitly realized that his writing helped him put the ideas from the discussion together.

Julie had a similar sense of the purpose of the writing, saying that the reason they were doing the writing was to "figure things out." This approaches the idea of writing to consolidate and review in which students put ideas together to begin to make sense of the content, or, in Julie's words, to help them "figure it out." However, Julie also said that it didn't help her figure anything out because she already knew everything about light. Again, this is reflected in her third journal entry (Figure 3) in which she gives terse responses that answer the question but go no further, the same as seen in her first journal entry. Following instruction, she was asked in the interview whether she would like to change any of her answers. She replied that no, she was satisfied with them including her answer of "20 feet" to question three--this, in spite of the fact that they had learned that, theoretically, a beam of light would continue to bounce off objects for a very long time; depending on the object, even an infinite amount of time.

Comparing written pre- and posttest data revealed that neither John nor Julie dramatically changed their concepts of the role of light in seeing. The way in which they perceived the writing tasks, as an arena for writing what they knew with no wrong answers, reinforced their belief in the accuracy of their prior knowledge. Using previous norms for why students write and for whom, they did not struggle to understand the scientific content but rather said that "it wasn't anything new" and "I already knew everything about light." Jane's comments in her journal, when they were eventually made late in the unit, most likely served to reinforce this belief. Typical

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[redacted] lo it didn't go thrax the hole.

2. It went on the black bord.

3. 20 feet

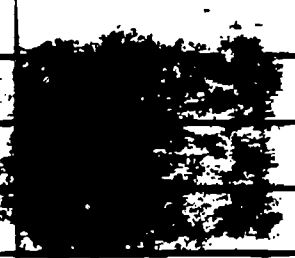

Figure 3. Julie's third journal entry.

comments were "good questions," "nice thinking," or "ok," which did not help push John's or Julie's thinking but rather reinforced the idea that Jane was looking for a right or wrong answer and that their ideas were "right."

Part III. Conclusions

Even with a limited sample of students writing over a short period, these cases reveal some general conclusions. Perhaps the most important is that students often have very strongly established norms for writing in subject matter areas even as early as the third grade. In order to help them change those norms, which is necessary if writing-to-learn is to serve its intended purpose, there is a need for extended discourse surrounding the writing task. Much as it is not enough in conceptual-change teaching to tell students their ideas are wrong and to give them the scientific concept, it is not enough to tell them that the purpose and audience for the writing differ from other writing they have done in subject matter. In a sense, the students also need to experience a process of conceptual change regarding the role the writing is to play in their learning and the ways in which they can use writing strategically to "help them learn," to use John's words .

As with conceptual-change teaching of subject matter in which students' prior knowledge strongly influences the way they interpret what the teacher says, their already established norms for writing in subject matter areas influence the way they interpret the audience and purpose of each writing task. As is seen with the examples of John and Julie, their well-established interpretations of audience and purpose strongly influenced not only the content and form of their writing, but also what was learned from the writing process.

Finally, it needs to be recognized that given these strongly held norms for both writing and subject matter learning, the process of teaching for conceptual change in science using writing as a tool is extremely difficult for both teacher and student. The teacher must go through a process of conceptual change regarding the typical school

norms for writing and the role that it can play in a subject matter area. In addition, he or she must go through a conceptual change regarding what it means to learn subject matter with understanding. In Jane's case, she had to abandon her existing concept of science teaching, which could be described as teaching as exposure, and develop an alternative concept of science teaching, which could be described as teaching as construction (of ideas).

Jane's existing concept (or prior knowledge) of science teaching and the role of writing in science was very strongly held, as were her students' concepts of light and seeing. Evidence of this is her tendency to use new strategies for oral and written discourse within her existing framework. In addition, Jane not only struggled with changing her own concepts, but also with changing her students' concepts of the role of writing in science and what it means to learn with understanding versus memorizing scientific terms. Evidence of this struggle is seen in the students' resistance and unwillingness, or inability, to see the journal writing as different from any writing that they had done that year, although Jane worked hard to help them see how it differed. Again, the result was that the writing didn't really work as she had planned.

The difficulties Jane encountered resulted in her slow reversal back to a more traditional way of teaching once she decided that the writing wasn't really working. Some of the problems with the writing in the unit that led to this decision were the ways in which the tasks themselves were structured. Although Jane intended them to extend the oral discourse, she tended to treat them as discrete entities, separate from other classroom discourse. This was seen most typically in the lack of discussion of the ideas prior to writing, possibly because Jane feared giving away the answers to the questions she wanted them to answer in their journals.

There was also a lack of genuine coexploration of the ideas in writing for teacher and students, which led to students seeing the writing as no different than any other writing done that year. For example, Jane did not respond to the ideas in their

journal until the very end of the unit. And the responses, when given, tended to reinforce the students' belief that there was indeed a right or wrong answer and that they had the correct answer. There was no ongoing dialogue in which Jane probed the students' ideas or pushed them on their thinking. More typically, she wrote comments such as "nice thinking" or "OK."

A final reason why the writing wasn't working was the way in which Jane attempted to change the classroom norms. Rather than show the students the new norms by puzzling with them over ideas or modeling her thinking about how to use the writing, Jane told them that the writing was to be different. The paradox was that while Jane tried to move away from a more didactic form of science teaching, she did so by didactically telling the students how it would differ.

In conclusion, using writing-to-learn has the potential for becoming a powerful tool for helping students through a process of conceptual change in science. However, both teachers and students hold school norms concerning both the nature of scientific knowledge and the role of subject matter writing, which make this task challenging and time-consuming for both. A change in these norms cannot come about in the course of one unit but rather must be developed by teacher and students together over the course of an entire school year.

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Appendix A

Sample Light Unit Writing Activities

**Writing activities are categorized by function. One possible audience is given after each activity.

I. Writing to draw on relevant knowledge:

A. Structured writing done prior to instruction (Could be used to establish the problem in a conceptual change unit)

1. Make of list of what you already know about light. This is not to be handed in, but rather to be updated as the unit progresses. (WRITING FOR SELF)

2. Write a paragraph telling why you think we see the moon at night. Will be handed in but not graded. Decide as a class on criteria for a good "idea". Get into groups and rate or nominate whose ideas are better and why. (WRITING FOR PEERS)

3. List the two most important things you know about light. To be compiled into a group list --individual list will not be turned in. No one except peers will see this list. (WRITING FOR SUBSET OF CLASSROOM PEERS)

4. List 5 things you know about light and rank according to how sure you are about their accuracy. (WRITING FOR SELF)

5. Fill in diagram showing how light helps us see an object (from Osborn & Freyburg, 1981). To be discussed/debated in class. (WRITING FOR SELF, POSSIBLY TO BE SHARED WITH PEERS)

6. Answer the question "where does the moon go at night?" using words, pictures, or both. Eventually to be made into a fact/fiction booklet to be published by the class. (WRITING FOR PEERS OR LARGER AUDIENCE UNKNOWN)

II. Writing for consolidation and review of knowledge
(Could be used at the "coaching" stage of a conceptual change unit)

A. At the end of instructional time or the start of next class:

1. "Scaffolded concept map"
i.e., Main framework determined as a class - new concepts from the days lesson added by individuals.

(WRITING FOR SELF)

2. Return to many of the tasks in Part I to write how ideas have changed, to add to lists, renominate from #2, re-rank from #3, determine which are "fact" and which are "fiction" in #6.
(SAME AUDIENCES AS PART I)

III. Writing to extend and reformulate knowledge
(Can be used to "coach" and "fade" in a conceptual change unit)

A. Application of unit concepts to real world object, or phenomenon.

1. Diagram the path that light takes when it hits the reflector on your bicycle.
(TO BE DEBATED AMONG SUBSET OF PEERS. A CONSENSUS DIAGRAM WILL BE DEVELOPED BY THE GROUP)

2. Design an instrument that will use light to tell you what is happening on the other side of a tall brick fence without climbing over or going around the fence. Diagram the instrument and then write an explanation (with scaffolded help from the teacher) of how it works. To be published in a "class inventions"book. Alternative: Write an interview for the 11:00 news describing the invention to the interviewer.
(AUDIENCE UNKNOWN)

Appendix B

Interview Protocol-Light Unit

You have been learning about light in your science class. I am going to ask you about some of the things you have been doing in class to help you learn about light.

Part I. General questions

1. You did some writing in science today (have writing available for the student to look at as they answer the questions). Who do you think will be reading this writing?

   Probe: Anybody else? If negative response follow up with cards listing possible audiences (you, Mrs. Peasley, the teacher, other kids in the class, a friend, your parents, the principal, other kids in the school)

   Probe: Which of these people do you think is the most important person reading what you wrote? Why?

   Probe: Who would you most like to have read what you wrote? Why?

   Probe: Which (if any) of these people would you feel you had to write very carefully for? What does "writing carefully" mean to you? Why do you have to write carefully for these people? Are there other people that you wouldn't have to be so careful when you were writing for them? Why don't you have to be so careful then?

   Probe: Did your teacher tell you why you did this writing assignment? If so: What did she say was the reason you were doing it? What do you think is the reason you did this assignment?

Part II. Getting at students' strategic use of the writing on specific tasks

1. Your teacher had you _____ today. Did this help you learn anything about light? What did it help you learn?

   Probe: Did you "discover" something about light that you didn't know before while you were writing? Tell me about that.

2. Was there anything you really liked about doing _____today? What was it?

   Probe: What did you like doing that? Probe on specifics on assignment.

3. Was there anything that disappointed or frustrated you about doing _____ today? Can you tell me about it?

Appendix C

Analysis of Student Interviews and Writing

The decision was made to do a qualitative case study rather than a quantitative analysis as this was introductory work with a very small sample, one classroom. The purpose was not to create generalizations, but rather to look closely at one teacher and her students' perceptions of writing tasks in science which were intended to be considerably different than the traditional writing tasks in this particular class.

It also became evident very early in the data analysis that looking at the writing by itself, out of context, while often very interesting, did not tell very much about what the student was thinking, or how they were using the writing. Therefore, the decision was made to analyze each writing assignment within the context of the discourse surrounding it, taking into account the students' interview reports of their thinking about the writing.

We were interested in particular whether there was agreement among the students as to their perceptions of the purpose and audience for the writing task, and how closely this agreed with Jane's enacted plans. Also of interest was whether the students' perceptions of the writing, and their strategic use of the writing, changed over the course of the unit. Analysis procedures then involved looking both between students on a given writing task to determine similarities and differences in their perceptions, and also to look at each student's writing across a series of tasks to determine if there was any change in their writing style.

The writing was not looked at as a separate entity, but rather was looked at in the context of the way in which it was introduced, the questions the students asked about the writing, and the discussion following the writing. In this sense it was considered as a part of the entire class discourse, rather than as an isolated entity. In addition analysis proceeded back and forth between the student interview data and the writing itself. In particular we were looking at the writing for evidence and examples that corresponded to what the students were saying about the writing, and also looking for times when the writing appeared to contradict what they were saying. Assertions were then formed regarding the way in which the students were thinking about the writing supported by evidence from the writing. These assertions served as the basis for further examination of writing and interviews looking for discrepant examples. If none were found the assertions were reported.